

APPENDIX C

Natural Hazard Risk Assessment

What Makes a Disaster?

A disaster is a natural or man-made emergency whose response needs exceed available resources. Thus, disasters are not just emergencies that make the national news!

There were 4,215 traffic-related fatalities in California in 2003, yet this was not called a “disaster.”²⁰

The number of homicides in California in 2003 was roughly half as large, with 2,402 deaths.²¹

Again, homicides aren’t disasters – unless committed in mass as an act of terrorism.

For comparison, all of the deaths associated with the September 11, 2001 attacks totaled 2,992²². In addition, the attacks caused billions of direct and indirect economic losses.

A single homicide is a crime, and an attack with political intent is terrorism. But both may not be a disaster.

Traffic-Related Fatalities in 2003

Alameda – 114
Contra Costa – 70
Marin – 13
Napa – 20
San Francisco – 52
San Mateo – 36
Santa Clara – 91
Solano – 56
Sonoma – 57
TOTAL = 509 in the Bay Area

Homicides in 2003

Alameda – 139
Contra Costa – 74
Marin – 0
Napa – 2
San Francisco – 69
San Mateo – 20
Santa Clara – 48
Solano – 20
Sonoma – 12
TOTAL = 384 in the Bay Area.

Deaths Associated with 9/11

2,749 deaths associated with the World Trade Center
184 deaths in the Pentagon tragedy
40 deaths when a hijacked jet crashed in Pennsylvania.
19 suicides by hijackers
TOTAL = 2,992

²⁰ Source – August 2004. National Highway Traffic Safety Administration. **2003 Annual Assessment of Motor Vehicle Crashes** (based on Fatality Analysis Reporting System – FARS): National Highway Traffic Safety Administration. Published at http://www-fars.nhtsa.dot.gov/finalreport.cfm?year=2003&stateid=6&title=States&title2=Fatalities and Fatality Rates&SpecialRpt=query1 county&SpecialRpt_lvl=2

²¹ Source – July 2004. California Department of Justice Criminal Justice Statistics Center. **Crime in California, 2003 Advance Release**: Attorney General's Office. Published at <http://ag.ca.gov/cjsc/publications/advrelease/ad/ad03/ad03.pdf>

²² Source – 2004. National Commission on Terrorist Attacks Upon the United States (9-11 Commission). **Final Report of the National Commission on Terrorist Attacks Upon the United States, Official Government Edition**. (Ch. 9, Footnote 188.) Published at <http://www.gpoaccess.gov/911/>

On the other hand, the San Simeon earthquake of December 2003 that resulted in only 2 fatalities, but caused hundreds of millions in property losses, was a disaster²³.

As stated above, disaster professionals define a disaster as a natural or man-made emergency whose response needs exceed available resources. When local government resources are exceeded, the California Governor's Office of Emergency Services (State OES) is contacted and the Governor is requested to declare a State Disaster. When State resources are exceeded, State OES contacts the U.S. Department of Homeland Security's Federal Emergency Management Agency (FEMA) and the President is requested to declare a National Disaster. This Presidential Declaration triggers funding resources for the public, the state, and local governments to use for clean-up, repair, recovery, and mitigation.

What Are Our Natural Hazards?

The focus of this effort is on *natural* hazards, that is, natural occurrences that can pose a risk of injury, loss of life, or damage to property. The nine most significant of these affecting the Bay Area, based on our past history, as well as on the State Hazard Mitigation Plan, are related to:

- ◆ earthquakes (*surface faulting, ground shaking, liquefaction, landslides, and tsunamis*), or
- ◆ weather (*flooding, landslides, wildfires, and drought*).

Other hazards relate to man-made conditions, including releases of hazardous materials, dam failures, energy shortages, and weapons of mass destruction. These other hazards are only addressed as they relate to earthquake and weather-related hazards. The only one of these additional hazards that is readily mapped and analyzed is *dam failure*.

Finally, people and the food they eat are subject to disease. These concerns are also not addressed in great detail, except as they relate to earthquake and weather-related hazards.

As part of this hazard identification process, ABAG has created a web site with access to 53 hazard maps. These maps are referenced to the "hard copy" maps in this document. However, these maps can be interactively zoomed by address, zip code, city, county, school district, fire jurisdiction, and water district for use in the preparation of local Annexes to this plan. They also are all publicly accessible on the web at <http://quake.abag.ca.gov/mitigation/>.

Why Are We Concerned with Exposure and Probability, Not Just Hazards?

If a river overflows its bank in an uninhabited area with no roads and no buildings, it is a flood, but not a flood disaster. If a major earthquake occurs in the desert of southeastern California where no one lives, it is still an earthquake, but not an earthquake disaster. Thus, this hazard mitigation plan is concerned about the location of people, buildings, and infrastructure relative to the hazards of floods, earthquakes, wildfires, and landslides – our hazard exposure.

²³ Source – 2004. FEMA. "President Orders Aid for California Earthquake Recovery." FEMA News Press Release HQ04-003. Published at <http://www.fema.gov/news/newsrelease.fema?id=10390>

Hazards also need to be expressed with some sort of probability. Typically, hazards that cause disasters are not common, or these disasters would have long ago triggered an increase in response capability and hazard mitigation. For example, Bay Area cities and counties have adopted mitigation strategies and building codes that allow moderate earthquakes to occur with minimal damage. Because these hazards cause rare disasters, the probability information on their future occurrence is incomplete or subject to large errors.

A complete risk assessment should identify:

- ◆ the existing land uses, buildings, infrastructure, and critical facilities located in each of these hazard areas (exposure);
- ◆ a general description of land use and development trends along with associated anticipated changes in exposure;
- ◆ an estimate of the potential deaths and injuries, property damages (dollar losses), and functional losses (disruption) based on exposure and vulnerability of various types of structures; and
- ◆ estimates of the probabilities of these losses over time.

The risk assessment ABAG is creating for the Bay Area is incomplete at this time. However, we anticipate that it will become more complete as we work with cities, counties, and special districts to incorporate additional information on critical and vulnerable facilities. ABAG plans to develop additional vulnerability information, as well as additional information on the potential impacts of mitigation strategies on vulnerability, from the fall of 2004 through the spring of 2006.

The following sections focus on describing the most significant natural hazards affecting the San Francisco Bay Area so that options for mitigation of those hazards can be developed.

What Is Hazard Mitigation?

There are two ways to deal with disasters.

1. We can increase emergency *response* capability. Thus, more damage needs to occur for those capabilities to be exceeded. Large incidents become manageable emergencies.
2. Projects can be undertaken to prevent or lessen the impacts of future incidents, and thus reduce the need for larger and larger response capability. Homes can be moved from areas suffering repeated floods. Buildings and infrastructure can be built to reduce expected damage in earthquakes. Wood shakes on homes in woodland areas can be replaced with asphalt shingles or tile. These actions are called “*mitigation*.”

More specifically, the Stafford Act defines “mitigation” as “*any sustained action taken to reduce or eliminate the long-term risk to human life and property from hazards.*”²⁴ Thus, as mitigation activities are undertaken, the risks associated with disasters decrease.

²⁴ Source – 44 CFR Section 201.2 pertaining to Section 322 of the Stafford Act, 42 U.S.C. 5165.

Earthquakes

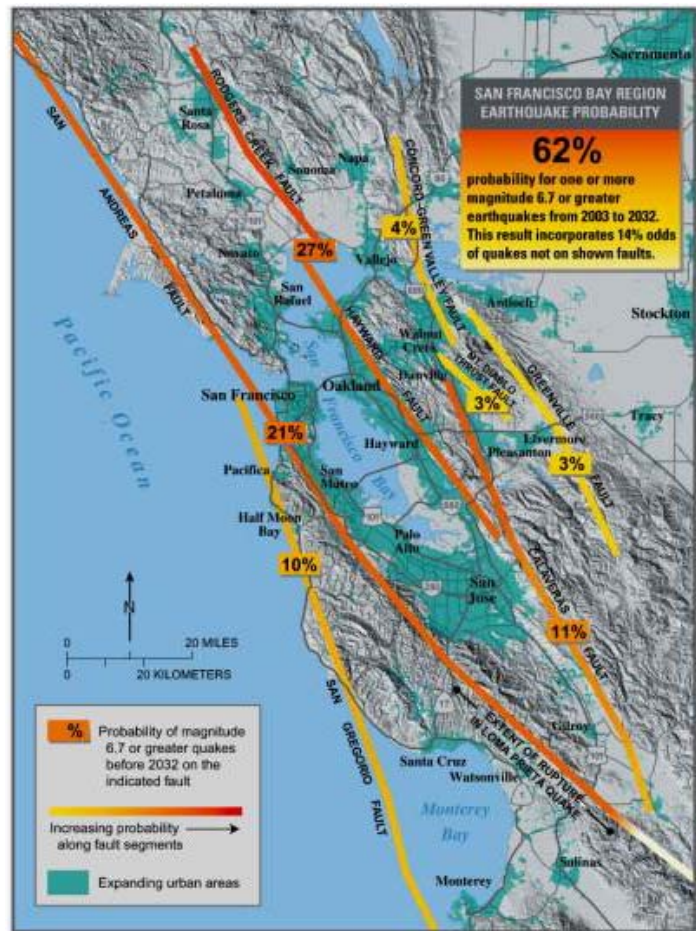
Probability of earthquake-related hazards

The Bay Area is in the heart of Earthquake Country. The Bay Area is crossed by many active faults. This map figure shows that major active faults run through or adjacent to all nine Bay Area counties.

While recent research by the U.S. Geological Survey (USGS) has provided more reliable probability information for future Bay Area earthquakes than for any other area of the country (62% of a magnitude 6.7 or larger earthquake), it has a wide error range – from a low of 37% to a high of 87%, or plus or minus 25%²⁵!

Probability information for the rupture of individual faults has also been prepared by USGS, as shown on the following table.²⁶

Note that there are major faults in the Bay Area, such as the West Napa fault and the Maacama fault, for which there is insufficient information to produce probability estimates.



Location and extent of earthquake-related hazards

Earthquakes result in five different hazards that have been mapped in the Bay Area. The following sections describe those hazards, as well as reference the map plates showing the location and extent of the hazard in the Bay Area.

Surface Rupture

Earthquakes occur in the Bay Area when forces underground cause the faults beneath us to rupture and suddenly slip. If the rupture extends to the surface, we see movement on a fault (**surface rupture**). Because faults are weaknesses in the rock, earthquakes tend to occur over and over on these same faults.

²⁵ Source – 2003. USGS Working Group on Earthquake Probabilities. *Is a Powerful Earthquake Likely to Strike in the Next 30 Years?* – USGS Fact Sheet 039-03 at <http://geopubs.wr.usgs.gov/fact-sheet/fs039-03/fs039-03.pdf> and *Earthquake Probabilities in the San Francisco Bay Region* - USGS Open-File Report 03-214 at <http://geopubs.wr.usgs.gov/open-file/of03-214/>.

²⁶ The probability information provided by the USGS for earthquakes on each fault also applies to the associated earthquake-related hazards (ground shaking, liquefaction, landslides, and, except for faults that do not extend to the surface, fault surface rupture). Tsunamis probabilities are more complicated, however, as noted on page 48 and 49.

TABLE 1 – Probabilities of Selected Earthquake Scenarios Occurring in the Next 30 Years and Slip Rates on Associated Fault Segments [based on USGS Working Group on California Earthquake Probabilities, 2003, except slip rates for last three faults from Petersen and others, 2002 update] [Scenario maps on ABAG web site are shaded.]

Fault	Segment (s)	Average Long-Term Slip Rate (mm / year)	% Probability of Characteristic Quake 2002-2031	% Probability of Quake ≥ 6.7 2002-2031
<i>San Andreas</i>	Santa Cruz Mountains (SAS)	17	2.6	2.5
	Peninsula (SAP)	17	4.4	4.3
	North Bay (SAN)	24	0.9	0.9
	Ocean (north of Bay Area – SAO)	24	0.9	0.9
	South Bay Segments (SAS + SAP)	17	3.5	3.5
	Central Bay Segments (SAP + SAN)	17 – 24	0.0	0.0
	Northern Segments (SAN + SAO)	24	3.4	3.4
	Bay Area Segments (SAS+SAP+SAN)	17 – 24	0.1	0.1
	Central + North (SAP + SAN + SAO)	17 – 24	0.2	0.2
	Entire – Repeat of 1906 (SAS + SAP + SAN + SAO)	17 – 24	4.7	4.7
	Floating M6.9	17 – 24	7.1	6.8
<i>Hayward/Rogers Creek</i>	Southern (HS)	9	11.3	4.3
	Northern (HN)	9	12.3	1.5
	Entire (HS + HN)	9	8.5	7.2
	Rogers Creek (RC)	9	15.2	14.4
	HN + RC	9	1.8	1.8
	HS + HN + RC	9	1.0	1.0
	Floating M6.9	9	0.7	0.7
<i>Calaveras</i>	Southern (Outside Bay Area - CS)	15	21.3	0.0
	Central (CC)	15	13.8	0.5
	CS + CC	15	5.0	0.5
	Northern (CN)	6	12.4	8.0
	CC + CN	6 – 15	0.3	0.2
	CS + CC + CN	6 – 15	2.0	1.8
	Floating M6.2	6 – 15	7.4	0.0
	Floating M6.2 on CS + CC	15	7.4	0.0
<i>Concord/Green Valley</i>	Concord (CON)	4	5.0	0.1
	Southern Green Valley (GVS)	5	2.3	0.0
	CON + GVS	4 – 5	1.6	0.3
	Northern Green Valley (GVN)	5	6.1	0.0
	Entire Green Valley (GVS + GVN)	5	3.2	0.4
	Entire (CON + GVS + GVN)	4 – 5	6.0	2.7
	Floating M6.2	4 – 5	6.2	0.0
<i>San Gregorio</i>	Southern (Outside Bay Area - SGS)	3	2.3	2.1
	Northern (SGN)	7	3.9	3.9
	SGS + SGN	3 – 7	2.6	2.6
	Floating M6.9	3 – 7	2.1	2.0
<i>Greenville</i>	Southern (GS)	2	3.1	0.7
	Northern (GN)	2	2.9	1.0
	Entire (GS + GN)	2	1.5	1.4
	Floating M6.2	2	0.4	0.0
<i>Mt. Diablo Thrust</i>	Mt. Diablo Thrust (MTD)	2	7.5	2.5
Maacama	Southern (part in Bay Area)	9	Not available	Not available
Monte Vista - Shannon	Monte Vista Segment	0.4	Not available	Not available
West Napa	Entire Segment	1	Not available	Not available

The California Geological Survey (CGS) publishes maps of the active faults in the Bay Area that reach the surface as part of its work to implement the requirements of the Alquist-Priolo Earthquake Fault Zone Act. These maps show not only the most comprehensive depiction of fault traces that can rupture the surface, but also the zones in which cities and counties must require special geologic studies to prevent the building of structures intended for human occupancy from being built *and* in which the surface rupture hazard must be disclosed in real estate transactions. The regional depiction of the location of this hazard is on **Plate 1 – Fault Surface Rupture Hazard**.

In some respects, fault rupture is a relatively minor problem in earthquakes. For example, strong earthquakes can occur when the fault rupture does not extend to the surface, and that fault-related damage is rare when compared to shaking-related damage. Neither the Loma Prieta nor the Northridge earthquakes resulted in surface rupture. In addition, the major thrust faults listed in Table 1 have not experienced surface rupture. While the faults shown on Plate 1 only include those faults that have experienced surface rupture, only structures that are directly astride the fault trace that ruptures will be damaged in a future earthquake, not all of the structures in the study zones.

That said, the amount of ground displacement can be quite large, particularly when a major strike-slip fault is involved. For example, in a study conducted by ABAG examining the potential impact of this hazard on road closures²⁷, the amount of horizontal displacement on the large strike-slip faults was estimated as 2 – 4 meters, and the amount of vertical displacement was estimated as 0 – 0.4 meters, with actual values sometimes reaching double these values.

Maps of fault rupture hazard for individual local governments are on line at <http://quake.abag.ca.gov/faults>.

Ground Shaking

The fault rupture of the ground generates vibrations or waves in the rock that we feel as **ground shaking**. Larger magnitude earthquakes generally cause a larger area of ground to shake hard, and to shake longer. Thus, one principal factor in determining shaking hazard is the magnitude of expected earthquakes. However, an earthquake shakes harder in one area versus another based not only on the magnitude, but also on other factors, including the distance of the area to the fault source of the earthquake and the type of geologic materials underlying the site, with stronger shaking occurring on softer soils. Earthquake intensity measures the strength of ground shaking in an individual earthquake at a particular location. ABAG and the U.S. Geological Survey (USGS) have developed several maps to aid in depicting shaking intensity, and thus ground shaking hazard.

- ◆ ABAG, in conjunction with scientists at USGS, has developed shaking intensity maps for 18 likely future earthquakes, as shown on **Plates 2 – 19 – ABAG Earthquake Shaking Scenarios**. These maps are appropriate for use in disaster exercises and in earthquake disaster planning.
- ◆ USGS has also developed several earthquake shaking intensity maps for anticipated future earthquakes. These maps are based on the ground motion models that are used to

²⁷ Source – 1997. Perkins, J., and others. *Riding Out Future Quakes* – ABAG, 198 pp. See fault rupture discussion on pages 15-19.

generate ShakeMaps for large and moderate earthquakes immediately after these earthquakes occur. A comparison of the USGS ShakeMap versus ABAG Earthquake Shaking Scenario map for the North and South Hayward fault scenario has been included as **Plate 20** for information. As can be seen from this comparison, the ABAG Earthquake Shaking Scenario maps show higher shaking near the fault than the ShakeMaps for the large strike-slip faults that are common in the Bay Area. Estimating ground motions near rupturing faults is an active area of earthquake research. Records of strong ground motions with peak velocities consistent with the ABAG model were obtained from near-fault stations for the recent 2002 Denali and 1999 Chi-Chi earthquakes. Because of our desire to be conservative, ABAG is using the ABAG Earthquake Shaking Scenario maps for this disaster planning effort.

As is obvious when examining the explanation on these maps, higher modified Mercalli intensities translate into higher shaking. The impact of this increased shaking varies. For example, higher shaking translates into higher numbers of landslides, greater areas of liquefaction, and more damaged buildings. More information on this subject is available at <http://www.abag.ca.gov/bayarea/eqmaps/doc/mmi.html> for the modified Mercalli intensity (MMI) scale itself, and at <http://www.abag.ca.gov/bayarea/eqmaps/doc/1998gs.html> for what higher ground shaking means in a way that is more quantified than the MMI scale itself. This information was developed by ABAG for the U.S. Geological Survey in 1998²⁸.

Finally, it is often useful to have a single hazard map containing the shaking hazard information for the Bay Area for long-term risk analysis. USGS cooperated with CGS, the California Seismic Safety Commission (CSSC), and State OES to develop such a “composite” scenario map. There are two principal caveats to use of this map. First, it incorporates probability information that has a wide margin of error. As stated earlier, while recent research by USGS has provided more reliable probability information for future Bay Area earthquakes than for any other area of the country (62% of a magnitude 6.7 or larger earthquake), it has a wide error range (from a low of 37% to a high of 87%, or plus or minus 25%²⁹)! In addition, the December 2003 San Simeon earthquake occurred in an area shown on this map as having less potential for strong shaking than many other areas of coastal California. The second caveat is that the shaking intensity levels are based on the ShakeMap models, and may underestimate the hazard near the Bay Area’s large strike-slip faults, as noted above. See **Plate 21 – Earthquake Shaking Potential** for a regional depiction of this hazard map.

See <http://quake.abag.ca.gov/mapsba.html> for more information and local government-specific depictions of these 20 earthquake shaking hazard maps.

Liquefaction

Ground shaking can lead to **liquefaction**. When the ground liquefies in an earthquake, sandy or silty materials saturated with water behave like a liquid, causing pipes to leak, roads and airport runways to buckle, and building foundations to be damaged. As with ground shaking, several types of maps aid in depicting this hazard.

²⁸ Source – 1998. Perkins, J. *The San Francisco Bay Area – On Shaky Ground - Supplement* – ABAG, 28 pp. See discussion on meaning of MMI on pages 2-11. Note – this information is also on the web at <http://www.abag.ca.gov/bayarea/eqmaps/doc/1998gs.html>.

²⁹ Source – 2003. USGS Working Group on Earthquake Probabilities. *Is a Powerful Earthquake Likely to Strike in the Next 30 Years?* – USGS Fact Sheet 039-03 at <http://geopubs.wr.usgs.gov/fact-sheet/fs039-03/fs039-03.pdf>.

- ◆ Liquefaction susceptibility maps show areas with water-saturated sandy and silty materials. **Plate 22** shows a map of liquefaction susceptibility for the Bay Area published by USGS showing various levels of liquefaction susceptibility. **Plate 23** shows the liquefaction susceptible areas as depicted by CGS. Unlike Plate 22, the map groups most of the moderate to very high susceptible areas shown on the USGS map into official seismic hazard map zones where real estate disclosure and hazard analysis are required. Note, however, that this type of map is only available for a portion of the Bay Area.
- ◆ Liquefaction hazard maps for specific earthquake scenarios show areas where the ground is both susceptible to liquefaction and that are likely to be shaken hard enough in a particular earthquake to trigger liquefaction. These maps are depicted in **Plates 24 – 41**.

ABAG has conducted extensive studies looking at the ways that liquefaction could potentially impact the Bay Area summarized in an ABAG report.³⁰ In general, the potential impacts to infrastructure are more significant than to building structures.

See <http://quake.abag.ca.gov/liquefac/liquefac.html> for more information and local government-specific depictions of these two liquefaction susceptibility and 18 liquefaction hazard maps.

Earthquake-Induced Landslides

Ground shaking can also lead to ground failure on slopes, or *earthquake-induced landslides*. While USGS has created several demonstration maps for this type of hazard, the best depiction is shown in **Plate 42**, the CGS seismic hazard map for earthquake-induced landslides. As with the CGS liquefaction susceptibility map, this map is only available for a portion of the Bay Area. The list of mitigation strategies includes several relating to ways in which local governments can increase the speed of completion of hazard maps, particularly GOVT-c-10, LAND-a-2, LAND-a-4, and LAND-a-5. ABAG is also working to secure funding for additional studies related to earthquake-induced landslide hazards in the Bay Area.

More detailed maps for individual local governments and additional landslide hazard information are available on line at <http://quake.abag.ca.gov/landslide>.

Tsunamis

Large underwater displacements from major earthquake fault ruptures or underwater landslides can lead to ocean waves called *tsunamis*.³¹ Since tsunamis have high velocities, the damage from a particular level of inundation is far greater than with a normal flood event. Tsunamis can result from off-shore earthquakes within the Bay Area, or from distant events.

A large effort is underway to develop tsunami hazard maps for the western coast of the United States. The State of California Governor's Office of Emergency Services (OES) is leading this effort. As of February 2005, a map of a portion of the Bay Area ocean coastline from San Gregorio in San Mateo County to Lincoln Park in San Francisco has been published. The map shows a "worst case" tsunami event for evacuation planning. The map is based on a maximum run-up to a specific contour, in this case, 12.8 meters (42 feet). While no maps of the area south

³⁰ Source – 2001. Perkins, J. *The San Francisco Bay Area – The Real Dirt on Liquefaction* – ABAG, 25 pp. See discussion on "What Happens to Our Built Environment" on pages 11-19. Note – this information is also on the web at <http://quake.abag.ca.gov/liquefac/liquefac.html>.

³¹ Waves in enclosed bodies, such as lakes or Bays, are called *seiches*. There are no published maps or hazard information on seiche hazards in the Bay Area.

of San Gregorio to the southern tip of San Mateo County have been published, the coastal bluffs in the area would tend to confine the inundation area to the beaches. The regional depiction of this hazard is on **Plate 43 – Tsunami Evacuation Planning Areas**. ABAG has worked with OES and the two affected counties to make the regional map, more detailed maps for individual local governments, and additional tsunami hazard information publicly available at <http://quake.abag.ca.gov/tsunami>.

Maps of the coastline portions of Sonoma and Marin counties are expected by fall 2005. No maps have been published as part of this OES effort for the area within San Francisco Bay, although an ongoing study³² indicates that if the run-up height is 10 meters at the Golden Gate, it might be half as high when it reaches the East Bay, and only 10% as high (1 meter) by the time it reaches the northern and southern ends of the Bay. ABAG continues to work with OES and the affected counties and hopes to make additional maps of this type available in the coming months.

It is important to understand that, even when the current OES mapping is complete, no probability information is available for the Bay Area tsunami hazard. ABAG and others are working with State OES to encourage more mapping that has an estimate of probability associated with it. OES and the California Geological Survey will be discussing this issue in a meeting tentatively scheduled for the fall of 2005. The tsunami hazard map is not even officially called a hazard map, but an evacuation planning map, because it is not based on probabilities.

The list of mitigation strategies includes several relating to ways in which local governments can increase the speed of completion of hazard maps, particularly GOVT-b-24 and GOVT-c-10.

Past occurrences of Bay Area earthquake-related disasters

The fact that a devastating earthquake occurred in 1906 – the San Francisco earthquake – is common knowledge. Larger earthquakes generally affect larger areas; the San Francisco earthquake caused extensive damage in Oakland, San Jose and Santa Rosa. More recently, the 1989 Loma Prieta earthquake caused extensive damage in the Santa Cruz Mountains, as well as in Oakland and San Francisco tens of miles away. But many moderate to great earthquakes (over magnitude 6.0) have affected the Bay Area; 22 such events have occurred in the last 160 years – for an average of one every seven years.

There have been only three earthquake-related natural disasters in the Bay Area since 1950 – the September 3, 2000 Napa earthquake (declared a disaster in only Napa County), the 1989 Loma Prieta earthquake (declared a disaster in Alameda, Contra Costa, Marin, San Francisco, San Mateo, Santa Clara, and Solano counties), and the April 1984 Morgan Hill earthquake (declared a disaster in Santa Clara County). In addition, the April 1964 Good Friday Alaskan earthquake triggered mitigation conducted for the tsunami warning in Marin County. See Appendix D and <http://quake.abag.ca.gov/mitigation/disaster-history.html>.

Vulnerability of the Bay Area to earthquakes

ABAG has focused its assessment of Bay Area earthquake vulnerability assessment by conducting several major analyses – three exposure analyses as part of its development of this

³² Dengler, L., Borrero, J., Patton, J., 2004. “The Tsunami Hazard in San Francisco Bay” in *Eos Trans.* AGU, 85(47), Fall Meet. Suppl., Abstract OS23D-1354.

multi-jurisdictional Local Hazard Mitigation Plan (with plans to conduct additional ones when more complete mapping is available), and three as part of earlier efforts.

Fault surface rupture hazard and exposure of existing land use –

The analysis of the types of land use and facilities focuses on the California Geological Survey's map of surface fault rupture hazard study zones (Plate 1) described earlier under the Alquist-Priolo Earthquake Fault Zoning Act. These zones are not fault zones, but zones in which studies are required to ensure that no structures intended for human occupancy are placed across active faults. Thus, only a small fraction of the land use areas and infrastructure miles in these zones are actually subject to fault rupture.

- ◆ Of the 4.36 million acres of land in the Bay Area, 1.8% is in areas designed as subject to the study requirement of the Alquist-Priolo Earthquake Fault Zoning Act.
- ◆ 2.2% of the urban land is in one of these areas, versus 1.7% of the non-urban land.
- ◆ Types of existing urban land uses with the highest percentages in these areas are urban open (3.1%), mixed residential-commercial (2.9%), and residential use (2.3%).
- ◆ The percentage of urban land located in these areas ranged from a high of over 4% in Alameda and San Mateo counties to a low of 0% in San Francisco.

These percentages are based on information in **Table 2: Surface Rupture Hazard and Existing (2000) Land Use**. See Plate 1 and <http://quake.abag.ca.gov/mitigation/pickdbh2.html> for more specific information for individual counties and cities.

Fault surface rupture hazard and exposure of existing infrastructure –

Rather than discuss the percentages of road miles in these areas, it is useful to note the number of road closures in these areas in various earthquake scenarios. See <http://www.abag.ca.gov/bayarea/eqmaps/eqtrans/result.html> and select a specific scenario. For example, of the 1,734 road closures expected in a future North-South Hayward fault earthquake, 520 will be due to surface rupture. (These estimates are an update of the ***Riding Out Future Quakes*** report discussed earlier.)

Pipelines have different issues, particularly the large water importation aqueducts of the East Bay Municipal Utility District (EBMUD), the Hetch-Hetchy system administered by the Public Utility Commission of the City and County of San Francisco (SF-PUC), and the Santa Clara Valley Water District. These local government agencies have unique issues with each major fault crossing. For example, EBMUD is continuing to work on its fault crossing issues, in spite of major construction projects that have already been completed.

Fault surface rupture hazard and exposure of existing critical facilities –

- ◆ Of the 812 critical health care facilities in the Bay Area, 1.8% are in areas designed as subject to the study requirement of the Alquist-Priolo Earthquake Fault Zoning Act.
- ◆ Only 1.1% of the 2,063 public schools are in these areas.
- ◆ Of the 3,991 critical facilities owned by cities, counties, and other special districts, 1.5% are in these areas.
- ◆ Of greater concern than a facility actually being astride a fault, however, is that the fault rupture will impede access and the functioning of infrastructure service to those facilities.

These percentages are based on information in **Table 2: Surface Rupture Hazard and Existing (2000) Land Use**. See Plate 1 and <http://quake.abag.ca.gov/mitigation/pickcrit.html> for more specific information for individual counties and cities.

TABLE 2: Surface Rupture Hazard and Existing (2000) Land Use

	In Alquist-Priolo Earthquake Fault Rupture Study Zones		% of Land in Study Zones
	Total Acres		
Total	4,395,975	81,300	1.8%
Urban	1,082,285	23,431	2.2%
Non-Urban	3,313,690	57,869	1.7%
URBAN ONLY:			
Residential	578,048	13,225	2.3%
Mixed R+C	2,345	68	2.9%
Commercial/ Services	100,396	2,072	2.1%
Mixed C+I	12,137	43	0.4%
Industrial	66,861	586	0.9%
Military	31,409	95	0.3%
Infrastructure	146,061	2,793	1.9%
Urban Open	145,028	4,547	3.1%
URBAN ONLY:			
Alameda	168,564	7,114	4.2%
Contra Costa	192,006	3,475	1.8%
Marin	52,784	723	1.4%
Napa	34,826	394	1.1%
San Francisco	29,187	0	0.0%
San Mateo	103,990	4,506	4.3%
Santa Clara	199,139	3,356	1.7%
Solano	102,317	930	0.9%
Sonoma	199,470	2,932	1.5%
	In Alquist-Priolo Earthquake Fault Rupture Study Zones		% of Miles in Study Zones
	Total Miles		
INFRASTRUCTURE:			
Roads	33,995	819	2.4%
Transit	173	1	0.6%
Rail	951	10	1.1%
Pipelines	32,022	762	2.4%
	In Alquist-Priolo Earthquake Fault Rupture Study Zones		% of Facilities in Study Zones
	Total Number		
CRITICAL FACILITIES:			
Health Care	812	15	1.8%
Schools	2,063	22	1.1%
Bridges	4,159	101	2.4%
Local Government	3,991	60	1.5%

See <http://quake.abag.ca.gov/mitigation/pickdbh2.html>
and <http://quake.abag.ca.gov/mitigation/pickcrit.html>
for more specific information.

Shaking hazard and exposure of existing land use –

Rather than perform this analysis for each of the many earthquake scenarios developed by USGS and ABAG, we have used the shaking potential map (Plate 21) described earlier.

- ◆ Of the 4.36 million acres of land in the Bay Area, 8.1% is in the areas with highest shaking potential, while 29.0% is in the next to highest area of shaking potential.
- ◆ 55.5% of the urban land is in one of these two areas, versus 31.1% of the non-urban land.
- ◆ Types of existing urban land uses with the highest percentages in these two areas are mixed commercial-industrial complexes (93.6%), mixed residential-commercial (80.7%), and commercial use (66.4%).
- ◆ Of the 115,986 acres of urban land in the highest shaking potential category, 47.1% is in residential use.
- ◆ The percentage of urban land located in the highest two shaking potential areas ranged from a high of over 78% in Alameda, San Francisco, San Mateo, and Santa Clara counties to lows of less than 7% in Napa and Solano counties.

These percentages are based on information in ***Table 3: Shaking Hazard and Existing (2000) Land Use***. See Plate 21 and <http://quake.abag.ca.gov/mitigation/pickdbh2.html> for more specific information for individual counties and cities.

Shaking hazard and exposure of existing infrastructure –

Rather than perform this analysis for each of the many earthquake scenarios developed by USGS and ABAG, we have used the shaking potential map (Plate 21) described earlier.

- ◆ A huge 86.7% of the fixed transit in the Bay Area is in the two highest shaking potential areas, including 84.8% of the BART lines. This finding on exposure is consistent with the BART effort to upgrade and strengthen its facilities.
- ◆ In comparison, 55.7% of the miles of roads, 56.8% of the rail lines, and 55% of the pipelines are in these areas.

These percentages are based on information in ***Table 3: Shaking Hazard and Existing (2000) Land Use***. See Plate 21 and <http://quake.abag.ca.gov/mitigation/pickdbh2.html> for more specific information for individual counties and cities.

Shaking hazard and exposure of existing critical facilities –

Rather than perform this analysis for each of the many earthquake scenarios developed by USGS and ABAG, we have used the shaking potential map (Plate 21) described earlier.

- ◆ Of the 812 critical health care facilities in the Bay Area, over three-quarters (77.7%) are in the two highest shaking potential areas.
- ◆ In addition, 70.1% of the 2,063 public schools are in the two highest shaking potential areas.
- ◆ Of the 3,991 critical facilities owned by cities, counties, and other special districts in the Bay Area, 72.8% are in the two highest shaking potential areas.
- ◆ These vulnerabilities show the need for more detailed risk assessment of these critical facilities, as addressed in the mitigation strategies in the areas of “Education” and “Government.” Many of these facilities have been seismically retrofitted or will require seismic retrofitting.

These percentages are based on information in ***Table 3: Shaking Hazard and Existing (2000) Land Use***. See Plate 21 and <http://quake.abag.ca.gov/mitigation/pickcrit.html> for more specific information for individual counties and cities.

TABLE 3: Shaking Potential and Existing (2000) Land Use

	Total Acres	Highest Shaking Potential	Next to Highest Shaking Potential	Middle Category of Shaking Potential	% of Land in Highest Shaking Potential Area	% of Land in Next to Highest Shaking Potential Area	% of Land in Middle Category of Shaking Potential
Total	4,395,975	357,325	1,273,997	1,865,606	8.1%	29.0%	42.4%
Urban	1,082,285	115,986	485,167	398,294	10.7%	44.8%	36.8%
Non-Urban	3,313,690	241,339	788,830	1,467,311	7.3%	23.8%	44.3%
URBAN ONLY:							
Residential	578,048	54,633	259,048	225,532	9.5%	44.8%	39.0%
Mixed R+C	2,345	484	1,409	415	20.6%	60.1%	17.7%
Commercial/Services	100,396	12,587	54,027	28,253	12.5%	53.8%	28.1%
Mixed C+I	12,137	1,593	9,762	639	13.1%	80.4%	5.3%
Industrial	66,861	5,159	35,346	21,790	7.7%	52.9%	32.6%
Military	31,409	5,082	5,491	17,848	16.2%	17.5%	56.8%
Infrastructure	146,061	20,307	56,345	51,107	13.9%	38.6%	35.0%
Urban Open	145,028	16,141	63,740	52,711	11.1%	44.0%	36.3%
URBAN ONLY:							
Alameda	168,564	26,148	110,737	27,730	15.5%	65.7%	16.5%
Contra Costa	192,006	6,997	76,521	96,105	3.6%	39.9%	50.1%
Marin	52,784	8,980	13,066	30,198	17.0%	24.8%	57.2%
Napa	34,826	137	980	20,400	0.4%	2.8%	58.6%
San Francisco	29,187	9,168	13,929	5,364	31.4%	47.7%	18.4%
San Mateo	103,990	37,455	55,559	7,428	36.0%	53.4%	7.1%
Santa Clara	199,139	7,758	148,023	42,853	3.9%	74.3%	21.5%
Solano	102,317	3,373	3,248	60,269	3.3%	3.2%	58.9%
Sonoma	199,470	15,621	62,350	108,352	7.8%	31.3%	54.3%
	Total Miles	Highest Shaking Potential	Next to Highest Shaking Potential	Middle Category of Shaking Potential	% of Miles in Highest Shaking Potential Area	% of Miles in Next to Highest Shaking Potential Area	% of Miles in Middle Category of Shaking Potential
INFRASTRUCTURE:							
Roads	33,995	3,619	15,307	12,107	10.6%	45.0%	35.6%
Transit	173	43	107	23	24.9%	61.8%	13.3%
Rail	951	143	397	329	15.0%	41.7%	34.6%
Pipelines	32,022	3,342	14,261	11,573	10.4%	44.5%	36.1%
	Total Number	Highest Shaking Potential	Next to Highest Shaking Potential	Middle Category of Shaking Potential	% of Facilities in Highest Shaking Potential Area	% of Miles in Next to Highest Shaking Potential Area	% of Facilities in Middle Category of Shaking Potential
CRITICAL FACILITIES:							
Health Care	812	141	490	168	17.4%	60.3%	20.7%
Schools	2,063	293	1,153	561	14.2%	55.9%	27.2%
Bridges	4,159	516	2,205	1,272	12.4%	53.0%	30.6%
Local Government	3,991	556	2,351	905	13.9%	58.9%	22.7%

See <http://quake.abag.ca.gov/mitigation/pickdbb2.html> and <http://quake.abag.ca.gov/mitigation/pickcrit.html> for more specific information.

Liquefaction susceptibility and exposure of existing land use –

Rather than perform this analysis for each of the earthquake scenarios developed by USGS and ABAG, we used the liquefaction susceptibility map (Plate 22) described earlier. The areas mapped as having moderate, high, and very high liquefaction susceptibility are roughly equivalent to the areas mapped by CGS as areas where studies are required (Plate 23).

- ◆ Of the 4.36 million acres of land in the Bay Area, 2.4% is in areas mapped as having very high liquefaction susceptibility, while 22.3% is the areas mapped in the combined moderate-high-very high liquefaction susceptibility category.
- ◆ 6.1% of the urban land is in the areas mapped as having very high liquefaction susceptibility, versus only 1.2% of the non-urban land.
- ◆ 39.1% of the urban land is in the areas mapped in the combined moderate-high-very high liquefaction susceptibility category, versus only 16.9% of the non-urban land.
- ◆ Types of existing urban land uses with the highest percentages in those areas mapped as having very high liquefaction susceptibility are mixed commercial-industrial complexes (18.6%), industrial (13.8%), military use (11.9%), and infrastructure (10.4%).
- ◆ The percentage of urban land located in these areas mapped as having very high liquefaction susceptibility ranged from a high of 16.8% in San Francisco to lows of less than 5% in Contra Costa, Napa, Santa Clara, Solano, and Sonoma counties.

These percentages are based on information in **Table 4: Liquefaction Susceptibility and Existing (2000) Land Use**. See Plate 22 and <http://quake.abag.ca.gov/mitigation/pickdbh2.html> for more specific information for individual counties and cities.

Liquefaction susceptibility and exposure of existing infrastructure –

Again, we have used the liquefaction susceptibility map (Plate 22) described earlier.

- ◆ Of the 33,995 miles of roads in the Bay Area, 4.6% are in areas mapped as having very high liquefaction susceptibility, while 27.9% are the areas mapped in the combined moderate-high-very high liquefaction susceptibility category.
- ◆ In comparison, 51.9% of the miles of rail, 34.6% of transit lines, and 27.5% of pipelines are in the combined moderate-high-very high liquefaction susceptibility category. These exposures are of concern because of the potential vulnerability of these lines to damage.

These percentages are based on information in **Table 4: Liquefaction Susceptibility and Existing (2000) Land Use**. See Plate 22 and <http://quake.abag.ca.gov/mitigation/pickdbh2.html> for more specific information for individual counties and cities.

Liquefaction susceptibility and exposure of existing critical facilities –

Again, we have used the liquefaction susceptibility map (Plate 22) described earlier.

- ◆ Of the 812 critical health care facilities in the Bay Area, 5.4% are in areas mapped as having very high liquefaction susceptibility, while 56.7% are the areas mapped in the combined moderate-high-very high liquefaction susceptibility category.
- ◆ Of the 2,063 public schools in the Bay Area, 4.8% are in areas mapped as having very high liquefaction susceptibility, while 50.8% are the areas mapped in the combined moderate-high-very high liquefaction susceptibility category.
- ◆ Of the 3,991 critical facilities owned by cities, counties, and other districts, 16.2% are in areas mapped as having very high liquefaction susceptibility, while 58.0% are the areas mapped in the combined moderate-high-very high liquefaction susceptibility category.

These percentages are based on information in **Table 4: Liquefaction Susceptibility and Existing (2000) Land Use**. See Plate 22 and <http://quake.abag.ca.gov/mitigation/pickcrit.html> for more specific information for individual counties and cities.

TABLE 4: Liquefaction Susceptibility and Existing (2000) Land Use

	Total Acres	Very High Liquefaction Susceptibility	High Liquefaction Susceptibility	Moderate Liquefaction Susceptibility	% of Land in Very High Liquefaction Susceptibility	% of Land in High Liquefaction Susceptibility	% of Land in Moderate Liquefaction Susceptibility
Total	4,395,975	104,836	446,496	429,906	2.4%	10.2%	9.8%
Urban	1,082,285	64,867	121,967	235,944	6.0%	11.3%	21.8%
Non-Urban	3,313,690	39,969	324,529	193,962	1.2%	9.8%	5.9%
URBAN ONLY:							
Residential	578,048	17,262	46,878	131,332	3.0%	8.1%	22.7%
Mixed R+C	2,345	196	264	870	8.4%	11.3%	37.1%
Commercial/ Services	100,396	7,505	12,133	33,521	7.5%	12.1%	33.4%
Mixed C+I	12,137	2,262	3,314	3,417	18.6%	27.3%	28.2%
Industrial	66,861	9,251	15,514	15,859	13.8%	23.2%	23.7%
Military	31,409	3,737	8,811	1,623	11.9%	28.1%	5.2%
Infrastructure	146,061	15,149	18,190	26,975	10.4%	12.5%	18.5%
Urban Open	145,028	9,505	16,863	22,347	6.6%	11.6%	15.4%
URBAN ONLY:							
Alameda	168,564	20,603	22,357	44,618	12.2%	13.3%	26.5%
Contra Costa	192,006	4,869	21,111	30,611	2.5%	11.0%	15.9%
Marin	52,784	5,354	8,001	4,779	10.1%	15.2%	9.1%
Napa	34,826	1,442	3,444	2,508	4.1%	9.9%	7.2%
San Francisco	29,187	4,898	456	9,187	16.8%	1.6%	31.5%
San Mateo	103,990	11,669	8,333	13,658	11.2%	8.0%	13.1%
Santa Clara	199,139	7,640	30,631	79,601	3.8%	15.4%	40.0%
Solano	102,317	3,678	9,667	24,002	3.6%	9.4%	23.5%
Sonoma	199,470	4,723	17,968	26,984	2.4%	9.0%	13.5%
	Total Miles	Very High Liquefaction Susceptibility	High Liquefaction Susceptibility	Moderate Liquefaction Susceptibility	% of Miles in Very High Liquefaction Susceptibility	% of Miles in High Liquefaction Susceptibility	% of Miles in Moderate Liquefaction Susceptibility
INFRASTRUCTURE:							
Roads	33,995	1,570	2,770	5,156	4.6%	8.1%	15.2%
Transit	173	14	11	38	8.1%	6.4%	22.0%
Rail	951	118	194	182	12.4%	20.4%	19.1%
Pipelines	32,022	1,361	2,607	4,828	4.3%	8.1%	15.1%
	Total Number	Very High Liquefaction Susceptibility	High Liquefaction Susceptibility	Moderate Liquefaction Susceptibility	% in Very High Liquefaction Susceptibility	% in High Liquefaction Susceptibility	% in Moderate Liquefaction Susceptibility
CRITICAL FACILITIES:							
Health Care	812	44	84	332	5.4%	10.3%	40.9%
Schools	2,063	100	228	719	4.8%	11.1%	34.9%
Bridges	4,159	528	706	1,329	12.7%	17.0%	32.0%
Local Government	3,991	646	607	1,063	16.2%	15.2%	26.6%

See <http://quake.abag.ca.gov/mitigation/pickdbb2.html> and <http://quake.abag.ca.gov/mitigation/pickcrit.html> for more specific information.

Earthquake-induced landslide susceptibility and exposure of existing land use, infrastructure, and critical facilities –

The best available map for showing earthquake-induced landslide susceptibility is the one prepared by CGS showing the areas where studies are required (Plate 42). The problem with any type of regional assessment using this map is that it does not cover the entire Bay Area. Thus, while the database of exposed land uses exists at <http://quake.abag.ca.gov/mitigation/pickdbh2.html>, the data for the region does not exist in a format for a regional analysis.

Housing damage due to earthquake ground shaking damage (last updated in 2003) –

- ◆ The 1989 Loma Prieta earthquake caused a total of over 16,000 units to be uninhabitable throughout the Monterey and San Francisco Bay Areas (including almost 13,000 in the Bay Area).
- ◆ As shown in ***Table 5: Predicted Uninhabitable Units for Bay Area Counties and Selected Earthquake Scenarios***, thirteen of 18 potential Bay Area earthquakes analyzed are expected to have a far larger impact than the Loma Prieta earthquake. In fact, ***eight*** of these earthquakes will probably have a greater impact than the 1994 Northridge earthquake in the Los Angeles area, where over 46,000 housing units were made uninhabitable.

See <http://www.abag.ca.gov/bayarea/eqmaps/eqhouse.html> for additional information.

Transportation system disruption due to earthquakes (last updated in 2003) –

- ◆ The 1989 Loma Prieta earthquake caused a total of only 142 road closures throughout the Monterey and San Francisco Bay Areas, whereas the Northridge earthquake resulted in only 140 road closures.
- ◆ As shown in ***Table 6: Predicted Road Closures for Bay Area Counties and Selected Earthquake Scenarios***, 16 of 18 potential Bay Area earthquakes analyzed are expected to have a far larger impact than either the Loma Prieta or the Northridge earthquake. In fact, ***five*** of these earthquakes are predicted to have over 1,000 road closures.
- ◆ One of the major causes of potential road and transit closures is BART.

See <http://www.abag.ca.gov/bayarea/eqmaps/eqtrans/eqtrans.html> for additional information.

Assessment of HAZUS for earthquake loss estimation (2003) –

- ◆ The 1994 Northridge earthquake caused over \$40 billion in losses, while the 1989 Loma Prieta earthquake caused about \$6 billion in losses.
- ◆ ABAG collaborated with USGS, CGS, and OES to write a paper on the results of several HAZUS³³ runs for earthquake-related losses associated with future scenario earthquakes.
- ◆ ABAG staff identified several potentially significant problems with using a combination of ShakeMap scenarios (which, as explained earlier, tend to produce shaking levels lower than the ABAG Shaking Scenario maps), the existing vulnerability formulas (which are prone to underestimate housing losses and losses to wood-frame structures such as dominate the building stock in the Bay Area), and incomplete building inventory data.
- ◆ ***These HAZUS loss estimates are inadequate for planning purposes at the present time.***
- ◆ See http://quake.abag.ca.gov/mitigation/HAZUS_Paper.pdf for the entire paper.

³³ HAZUS is a software package developed by FEMA for loss modeling.

TABLE 5: Predicted Uninhabitable Units for Bay Area Counties and Selected Earthquake Scenarios

Earthquake Scenario	Alameda	Contra Costa	Marin	Napa	San Francisco	San Mateo	Santa Clara	Solano	Sonoma	TOTAL
Santa Cruz Mts.-San Andreas	1,968	159	297	0	11,781	223	1,277	2	3	15,710
Peninsula-Golden Gate San Andreas	3,820	188	1,485	3	65,316	22,525	15,094	11	42	108,484
Northern Golden Gate San Andreas	4,345	560	2,988	19	62,654	1,904	449	127	1,804	74,851
Entire Bay Area San Andreas	16,048	1,173	3,495	20	82,354	24,472	29,593	185	2,530	159,870
No. San Gregorio	3,104	238	1,176	4	38,306	9,040	589	12	45	52,514
So. Hayward	64,451	1,760	1,030	16	13,940	245	11,892	126	37	93,497
No. Hayward	43,132	7,686	1,653	19	11,464	210	303	128	74	64,669
N + S Hayward	88,265	10,102	2,125	36	37,670	1,616	14,273	1,046	559	155,692
Rodgers Creek	3,688	1,418	1,549	53	11,460	151	100	1,148	13,988	33,555
Rodgers Creek-No. Hayward	49,284	9,786	2,691	713	29,758	363	402	1,386	14,115	108,498
So. Maacama	325	17	27	22	1,986	11	11	15	825	3,239
West Napa	1,382	286	27	4,284	2,011	15	29	1,668	126	9,828
Concord-Green Valley	3,511	11,363	29	1,307	3,191	76	325	2,868	37	22,707
No. Calaveras	7,836	3,509	27	18	3,191	78	4,882	181	6	19,728
Central Calaveras	3,037	75	27	3	3,191	182	10,145	13	4	16,677
Mt. Diablo	6,128	4,868	751	3	10,489	23	109	17	4	22,392
Greenville	2,701	2,637	27	19	2,005	16	101	190	6	7,701
Monte Vista	323	5	16	1	2,429	2,392	27,223	2	2	32,393

TABLE NOTES – This table is based on ABAG’s modeling of uninhabitable housing units in future earthquake scenarios (*Shaken Awake!*, Perkins and others, 1996) that was last updated in 2003 for consistency with U.S. Geological Survey earthquake scenarios released at that time. This modeling is based on an extensive statistical analysis of the housing damage which occurred as a result of the 1989 Loma Prieta and 1994 Northridge earthquakes. However, the expected percentage of pre-1940 single-family homes rendered uninhabitable used to generate this table is larger than published in 1996. New data on lack of retrofitting and reasons for low damage in the Northridge earthquake caused ABAG to increase the uninhabitable percentages used to create this table for pre-1940 single-family homes to 19% and 25% for MMI IX and X, respectively.

Note that several fault segments listed above have new segment end points or were not included in the 1996 report. They are included in this table to

reflect ground shaking information published by USGS in 2003. The Santa Cruz Mts.–San Andreas is similar, but not identical, to the fault causing the Loma Prieta earthquake. The Monte Vista and West Napa faults have been added to the faults analyzed by USGS to illustrate the impact of an earthquake in these areas. The Maacama fault could impact the North Bay, but too little was known about the fault for the USGS to issue probabilities for it in 2003. It, too, has been added to illustrate possible damage. On the other hand, the Southern Calaveras, the Southern San Gregorio, and the northern North Coast–San Andreas faults are outside of the Bay Area. The Bay Area impacts of earthquakes on these fault segments are dwarfed by their Bay Area segments so they are not included. Additional information on earthquakes and housing is available in *Shaken Awake!* and on the ABAG Earthquake Program Internet site at <http://quake.abag.ca.gov>.

TABLE 6: Predicted Road Closures for Bay Area Counties and Selected Earthquake Scenarios

Earthquake Scenario	Alameda	Contra Costa	Marin	Napa	San Francisco	San Mateo	Santa Clara	Solano	Sonoma	TOTAL
Santa Cruz Mts.-San Andreas	24	10	3	0	44	9	64	0	1	154
Peninsula-Golden Gate San Andreas	50	9	22	0	335	300	146	1	4	866
Northern Golden Gate San Andreas	62	20	70	1	321	24	10	4	69	581
Entire Bay Area San Andreas	146	30	77	3	429	315	250	6	75	1,332
No. San Gregorio	43	11	20	0	164	144	13	1	6	401
So. Hayward	901	43	15	1	72	8	90	4	4	1,138
No. Hayward	335	238	20	1	48	5	7	5	8	667
N + S Hayward	1,081	268	28	2	214	16	99	10	16	1,734
Rodgers Creek	54	34	20	4	48	3	3	12	223	4
Rodgers Creek-No. Hayward	363	256	34	9	157	11	10	14	230	1,084
So. Maacama	8	3	1	3	6	0	1	1	53	74
West Napa	22	20	1	89	6	1	1	14	5	159
Concord-Green Valley	56	201	1	19	11	3	7	83	4	386
No. Calaveras	180	107	1	1	11	3	53	6	1	363
Central Calaveras	51	10	1	0	11	4	132	1	1	210
Mt. Diablo	94	78	7	0	41	2	4	2	1	228
Greenville	70	47	1	1	6	1	4	6	1	138
Monte Vista	10	1	0	0	8	23	283	0	1	326

TABLE NOTES – This table is based on ABAG’s modeling of road closures in future earthquake scenarios (*Riding Out Future Quakes*, Perkins and others, 1997) that was last updated in 2003 for consistency with U.S. Geological Survey earthquake scenarios released at that time. This modeling is based on an extensive statistical analysis of the road closures which occurred as a result of the 1989 Loma Prieta and 1994 Northridge earthquakes.

Note that several fault segments listed above have new segment end points or were not included in the 1996 report. They are included in this table to reflect ground shaking information published by USGS in 2003. The Santa Cruz Mts.–San Andreas is similar, but not identical, to the fault causing the Loma Prieta earthquake. The Monte Vista and West Napa

faults have been added to the faults analyzed by USGS to illustrate the impact of an earthquake in these areas. The Maacama fault could impact the North Bay, but too little was known about the fault for the USGS to issue probabilities for it in 2003. It, too, has been added to illustrate possible damage. On the other hand, the Southern Calaveras, the Southern San Gregorio, and the northern North Coast–San Andreas faults are outside of the Bay Area. The Bay Area impacts of earthquakes on these fault segments are dwarfed by their Bay Area segments so they are not included. Additional information on earthquakes and housing is available in *Riding Out Future Quakes* and on the ABAG Earthquake Program Internet site at <http://quake.abag.ca.gov>.

Tsunamis and exposure of existing land use and infrastructure –

ABAG has not performed any analysis of the land use and infrastructure exposure within the tsunami evacuation areas as part of this Local Hazard Mitigation Plan. This exposure data is also not available on ABAG's internet site. The maps are too preliminary and only cover a fraction of the coastline. In addition, the California Governor's Office of Emergency Services has stressed that these maps are NOT appropriate for anything but evacuation planning.

Additional earthquake risk assessment plans –

In addition, ABAG is in the process of conducting additional analyses on privately-owned hazardous buildings in earthquakes (initially to focus on unreinforced masonry buildings). These analyses will be completed after ABAG receives data from the cities and counties.

Weather

Weather-related hazards – probabilities, location, and extent

Weather can result in three different hazards that have been mapped in this plan, as well as one that has not been mapped. First, large winter storms can result in flooding, landslides, and coastal erosion.

Flooding

The Federal Emergency Management Agency has mapped ***flooding*** hazards in the Bay Area's low-lying areas. These flood hazard maps have built-in probability information – the 100-year floodplain or the 500-year floodplain. ***Plate 44*** depicts the 100-year flood zone for the Bay Area, as well as the zone for 500-year floods and other concerns. More detailed maps for individual local governments and additional landslide hazard information are available on line at <http://www.abag.ca.gov/bayarea/eqmaps/eqfloods/floods.html>.

The maps available on the ABAG web site do not include information on depth of flooding, except that the 500-year flood areas also include areas subject to 100-year flood events with flooding depths expected to be less than one foot.

[Note that flooding associated with tsunami hazards are covered above under earthquake-related hazards, not as part of flooding in this discussion.]

Landslides

These same storms also impact our hillsides by triggering debris flows and more slow-moving traditional landslides. The U.S. Geological Survey has developed maps depicting both **debris flow** source areas (**Plate 45**) and **existing landslides** (**Plate 46**). The map of existing landslides covers areas of severe coastal erosion.

No formal estimates of probability are associated with these maps and there is no way to estimate these probabilities within the scope of this initial Local Hazard Mitigation Plan. There is also no way to estimate the scale of individual landslides in terms of size or extent based on these maps. The list of mitigation strategies includes several relating to ways in which local governments can increase the speed of completion of hazard maps, particularly GOVT-c-10, LAND-a-2, LAND-a-4, and LAND-a-5. ABAG is also working to secure funding for additional studies related to rainfall-induced landslide hazards in the Bay Area.

More detailed maps for individual local governments and additional landslide hazard information are available on line at <http://quake.abag.ca.gov/landslide>.

Wildfire

Just as weather can result in too much water, the Bay Area's weather can result in too little water. One of the resulting hazards is **wildfire**. The California Department of Forestry has developed state-of-the-art maps depicting wildfire hazard areas. The two most useful maps are those depicting Wildland Urban Interface (WUI) wildfire threat (**Plate 47**) and wildfire threat from wildland fuels in State Responsibility Areas (**Plate 48**). Additional maps include a map of perimeters of past large fires (300 acre minimum for CDF fires since 1950 and 10 acre minimum for USFS fires since 1910 (**Plate 49**), a map of fire-related risks to ecosystem health as measured by condition class (**Plate 50**), a map of the distribution of wildland-urban-interface housing unit density (**Plate 51**), and a map of post-fire risk of increased surface erosion (**Plate 52**). More detailed maps for individual local governments and additional wildfire hazard information are available on line at <http://quake.abag.ca.gov/wildfire>.

Using a combination of the map of past wildfires (Plate 49) in combination with the fire threat maps (Plates 47 and 48), a table of the probability of an area burning in the next 50 years can be calculated. Based on an analysis of data on wildfires during the past 50 years, 27% of the areas mapped as an extreme wildfire threat have burned, 23% of those mapped as very high, and 14% of those mapped as high. In addition, 4.3% of the areas in wildland-urban-interface fire threat areas have burned.³⁴ Thus, the probability of the areas mapped as very high hazard on the wildfire threat is much greater than those mapped on the wildland-urban-interface fire threat map. On the other hand, the wildland-urban-interface fire threat map shows more urban areas with a greater potential property value.

More specific results of this analysis are shown in **Table 7: Estimate of Probability of Fire Affecting a Given Area Based on Data from Past 50 Years**.

³⁴ Source – Data from analysis of California Department of Forestry maps at <http://www.abag.ca.gov/bayarea/eqmaps/wildfire/>. (Also see Table 5.)

**TABLE 7: Estimate of Probability of Fire Affecting a Given Area
Based on Data from Past 50 Years**

Threat Category	Acres Burned in Past 50 Years	Total Number of Acres Within Threat Classification	Percent of Acres That Burned in Past 50-Year Period
On Wildfire Threat Map			
Little or no threat	16,109	600,703	2.68%
Moderate	23,333	1,168,996	2.00%
High	159,681	1,152,490	13.86%
Very High	312,034	1,366,544	22.83%
Extreme	23,012	84,661	27.18%
On Wildland Urban Interface Fire Threat Map			
WUI Acres	34,652	810,757	4.27%

Drought and Dam Failure

While the Bay Area’s annual six-month dry season is associated with an annual wildfire “season” in the fall, what would be a **drought** in other areas of the country is controlled in this region through the importation of water and the storage of water in reservoirs. Occasionally, the impacts of prolonged periods of drought cause additional drought-related problems, including crop losses and shortages of water for landscaping.

Drought can impact the entire Bay Area, not just one particular county or a few cities. In addition, shortages in precipitation in the Sierra Nevada can have a more pronounced impact on water supply in the region than a drought in the Bay Area itself. Thus, drought is not a hazard that can be depicted in map form.

There is also no current data on the probability of drought that would be comparable to the USGS effort on earthquakes in the region, or the way 100-year flood maps are created. Such an effort has been proposed by the Western Governors’ Association, most recently in 2003. See <http://www.westgov.org/wga/initiatives/drought2.htm> for more information.

The list of mitigation strategies includes several relating to ways in which local governments can help efforts to increase the knowledge of this hazard and/or plan for its impacts, particularly GOVT-c-10, ENVI-a-3, ENVI-a-4, ENVI-a-6, ENVI-a-7, and ENVI-b-1.

On the other hand, the dams built to hold the water in reservoirs can be damaged, due to a huge storm and associated runoff, an earthquake, or a terrorism event. Maps depicting the areas that might be inundated were prepared by the dam owners. No probability information is available for the Bay Area dam failure hazard. These maps have been generalized into a single regional map (*Plate 53*). More detailed maps for individual local governments and additional dam failure hazard information are available on line at <http://www.abag.ca.gov/bayarea/eqmaps/damfailure/damfail.html>.

Other Weather Concerns Not Addressed Directly as Part of This Plan

Similarly, the Bay Area can have days that exceed 100°F. These **heat** waves would be more life-threatening if it were not for the common availability of air conditioning. Thus, this hazard is not dealt with as part of this Local Hazard Mitigation Plan.

Finally, the Bay Area, particularly its crops, can be subject to extensive damage due to **freezes**. Freezing conditions also cause die back of vegetation that can become fuel for the subsequent fire seasons. This issue has been especially problematic for the Bay Area's eucalyptus trees. Again, this hazard is not something that can be easily depicted in map form. The hazard itself can be mitigated, however. Some available strategies are included in Local Hazard Mitigation Plan when dealing with the more general wildfire hazard.

Past occurrences of Bay Area weather-related disasters

Flooding, storms, landslides, droughts, and wildfires have been among the most common disasters in the Bay Area during the period from 1950 to 2000.

- ◆ Extensive flooding and/or landslides occurred in 1950, 1955, 1957, 1958, 1959, 1962, 1963, 1964, 1965, 1966, 1969, 1970, 1973, 1980, 1982, 1983, 1992, 1995, 1996, 1997, and 1998.
- ◆ Large wildfires occurred in 1961, 1962, 1964, 1965, 1970, 1981, 1985, 1988, and 1991.
- ◆ Major droughts were in 1973 and 1976.
- ◆ Freezing conditions caused emergency conditions in 1970, 1972, 1973, and 1990.
- ◆ While dams have failed elsewhere, a dam has never failed in the Bay Area.

See Appendix D and <http://quake.abag.ca.gov/mitigation/disaster-history.html> for more specific information.

Vulnerability of the Bay Area to weather-related disasters

ABAG has focused its assessment of weather-related vulnerability by examining the existing land uses in mapped hazard areas.

Flooding and exposure of existing land use –

- ◆ Of the 4.36 million acres of land in the Bay Area, 9.4% is in the 100-year flood zone, while only 2.1% is in the 500-year flood zone or area of other flooding concern.
- ◆ 8.9 % of the urban land is in the 100-year flood zone, versus 9.6% of the non-urban land.
- ◆ 4.9% of the urban land is in the 500-year flood zone or area of other concern, versus only 1.2% of the non-urban land. The fact that over four times the percentage of urban versus non-urban land is in these areas is because lands protected from 100-year flooding are in these areas of “other flooding concerns.”
- ◆ Types of existing urban land uses with the highest percentages in 100-year flood zones are mixed commercial-industrial complexes (22.7%), urban open space (19.7%), and military use (15.4%).
- ◆ The percentage of urban land located in the 100-year flood zone ranged from a high of 13.9% in Solano County and 12.2% in Marin County to lows of 0% in San Francisco and 4.6% in San Mateo County.

These percentages are based on information in ***Table 8: Flooding Hazards and Existing (2000) Land Use***. See Plate 44 and <http://quake.abag.ca.gov/mitigation/pickdbh2.html> for more specific information for individual counties and cities.

Flooding and exposure of existing infrastructure –

- ◆ Rail is disproportionately located in zones subject to 100-year floods, with 19.7% of the miles of track located in these areas.
- ◆ Pipelines, as underground lines, should not be impacted by flooding even though 4.5% of the miles of pipelines in the region are in these areas.
- ◆ While 6.4% of the transit lines are in these areas, this statistic simply points to a need for further assessment on the part of transit operators. For example, underground BART stations are more vulnerable to potential flooding than are elevated track.

TABLE 8: Flooding Hazards and Existing (2000) Land Use

	Total Acres	Within 100- Year Flood Zone	Within 500-Year Flood Zone or Other Area of Concern	% of Land Within 100- Year Flood Zone	% of Land Within 500- Year Flood Zone or Other Area of Concern
Total	4,395,975	413,595	93,452	9.4%	2.1%
Urban	1,082,285	96,067	52,706	8.9%	4.9%
Non-Urban	3,313,690	317,529	40,746	9.6%	1.2%
URBAN ONLY:					
Residential	578,048	26,016	28,125	4.5%	4.9%
Mixed R+C	2,345	195	91	8.3%	3.9%
Commercial/ Services	100,396	8,538	6,365	8.5%	6.3%
Mixed C+I	12,137	2,750	1,624	22.7%	13.4%
Industrial	66,861	9,871	4,148	14.8%	6.2%
Military	31,409	4,834	53	15.4%	0.2%
Infrastructure	146,061	15,320	5,905	10.5%	4.0%
Urban Open	145,028	28,543	6,396	19.7%	4.4%
URBAN ONLY:					
Alameda	168,564	10,868	9,250	6.4%	5.5%
Contra Costa	192,006	12,820	4,100	6.7%	2.1%
Marin	52,784	6,457	2,893	12.2%	5.5%
Napa	34,826	3,631	475	10.4%	1.4%
San Francisco	29,187	0	0	0.0%	0.0%
San Mateo	103,990	4,816	4,043	4.6%	3.9%
Santa Clara	199,139	22,885	23,636	11.5%	11.9%
Solano	102,317	14,250	4,298	13.9%	4.2%
Sonoma	199,470	20,340	4,011	10.2%	2.0%
	Total Miles	Within 100- Year Flood Zone	Within 500-Year Flood Zone or Other Area of Concern	% of Miles Within 100- Year Flood Zone	% of Miles Within 500- Year Flood Zone or Other Area of Concern
INFRASTRUCTURE:					
Roads	33,995	2,487	1,561	7.3%	4.6%
Transit	173	11	4	6.4%	2.3%
Rail	951	187	56	19.7%	5.9%
Pipelines	32,022	2,288	1,440	7.1%	4.5%
	Total Number	Within 100- Year Flood Zone	Within 500-Year Flood Zone or Other Area of Concern	% Within 100-Year Flood Zone	% Within 500-Year Flood Zone or Other Area of Concern
CRITICAL FACILITIES:					
Health Care	812	33	56	4.1%	6.9%
Schools	2,063	80	121	3.9%	5.9%
Bridges	4,159	697	318	16.8%	7.6%
Local Government	3,991	370	352	9.3%	8.8%

See <http://quake.abag.ca.gov/mitigation/pickdbh2.html> and <http://quake.abag.ca.gov/mitigation/pickcrit.html> for more specific information.

These percentages are based on information in *Table 8: Flooding Hazards and Existing (2000) Land Use*. See Plate 44 and <http://quake.abag.ca.gov/mitigation/pickdbh2.html> for more specific information for individual counties and cities.

Flooding and exposure of existing critical facilities –

- ◆ Of the 812 critical health care facilities in the Bay Area, 6.9% are in zones subject to 100-year floods.
- ◆ Of the 2,063 public schools in the Bay Area, 5.9% are in zones subject to 100-year floods.
- ◆ Of the 3,991 critical facilities owned by cities, counties, and other districts, 9.3% are in zones subject to 100-year floods.

These percentages are based on information in *Table 8: Flooding Hazards and Existing (2000) Land Use*. See Plate 44 and <http://quake.abag.ca.gov/mitigation/pickcrit.html> for more specific information for individual counties and cities.

Repetitive flood losses –

The Federal Emergency Management Agency (FEMA) insures properties against flooding losses in the Bay Area through the National Flood Insurance Program. Those properties that have had more than one insured flood loss are called "repetitive loss properties." There are 1,158 properties that have experienced repetitive losses in the Bay Area, resulting in a total of 3,218 claims totaling \$64,032,056. A total of 921 of the properties are located in the 100-year flood plain. An additional 80 are located in the areas mapped as a 500-year flood zone or area of other concern. The remaining 157 properties are located outside of these mapped hazard areas.

Most of these properties (67%) are located in Sonoma County. An even higher percentage of the claims (69.6%) and insured losses (73.6%) are located in this county. Almost all of these losses occurred in the unincorporated portion of that county. See *Table 9: Repetitive Flood Losses* for data summarized by county and <http://quake.abag.ca.gov/mitigation/pickflood.html> for more specific information for individual counties and cities.

TABLE 9: Repetitive Flood Losses

	Total Number of Properties	Within 100-Year Flood Zone	Within 500- Year Flood Zone or Other Area of Concern	Not Within the Mapped Flood Zone	Number of Claims
Total	1,158	921	80	157	3,218
Alameda	10	2	0	8	20
Contra Costa	46	29	9	8	103
Marin	149	124	6	19	398
Napa	95	67	7	21	247
San Francisco	4	0	0	4	11
San Mateo	23	8	4	11	56
Santa Clara	27	19	4	4	67
Solano	28	22	5	1	76
Sonoma	776	650	45	81	2,240

See <http://quake.abag.ca.gov/mitigation/pickflood.html> for more specific information.

Existing landslide areas and existing land use –

- ◆ Of the 4.36 million acres of land in the Bay Area, 23.0% are in areas mapped as mostly landslides on the existing landslide map.
- ◆ Only 8.3% of the urban land is in these mostly landslide areas, versus 27.9% of the non-urban land.
- ◆ Types of existing urban land uses with the highest percentages in these mostly landslide areas are urban open space (14.1%) and residential use (9.3%).
- ◆ Of the 89,647 acres of urban land in these areas of extensive landslides, 59.8% is residential use.
- ◆ The percentage of urban land located in these mostly landslide areas ranged from a high of 18.2% in Marin County, 13.2% in Contra Costa County, and 12.5% in Sonoma County to a low of 1% in San Francisco.

These percentages are based on information in ***Table 10: Existing Landslide Areas and Existing (2000) Land Use***. See Plate 46 and <http://quake.abag.ca.gov/mitigation/pickdbh2.html> for more specific information for individual counties and cities.

Existing landslide areas and existing infrastructure –

- ◆ While 11% of the miles of pipelines and 10.6% of the miles of roads are in areas mapped as mostly landslides, only 2.3% of the miles of transit miles and 1.3% of the rail miles are in these areas.
- ◆ The exposure of pipelines and roads to landslide hazards is greatest in Marin County, where 23.1% of the pipelines and 22.5% of the roads are in these areas of existing landslides.

These percentages are based on information in ***Table 10: Existing Landslide Areas and Existing (2000) Land Use***. See Plate 46 and <http://quake.abag.ca.gov/mitigation/pickdbh2.html> for more specific information for individual counties and cities.

Existing landslide areas and existing critical facilities –

- ◆ Of the 812 critical health care facilities in the Bay Area, only 0.5% are in areas mapped as mostly landslides on the existing landslide map.
- ◆ Of the 2,063 public schools in the Bay Area, only 1.0% are in areas mapped as mostly landslides on the existing landslide map.
- ◆ Of the 3,991 critical facilities owned by cities, counties, and other special districts in the Bay Area, 2.7% are in areas mapped as mostly landslides on the existing landslide map.

These percentages are based on information in ***Table 10: Existing Landslide Areas and Existing (2000) Land Use***. See Plate 46 and <http://quake.abag.ca.gov/mitigation/pickcrit.html>, for more specific information for individual counties and cities.

TABLE 10: Existing Landslide Areas and Existing (2000) Land Use

	Total Acres	In Areas of Mostly Landslides	% of Land in Areas of Mostly Landslides
Total	4,395,975	1,012,701	23.0%
Urban	1,082,285	89,647	8.3%
Non-Urban	3,313,690	923,054	27.9%
URBAN ONLY:			
Residential	578,048	53,606	9.3%
Mixed R+C	2,345	6	0.3%
Commercial/ Services	100,396	3,758	3.7%
Mixed C+I	12,137	89	0.7%
Industrial	66,861	2,416	3.6%
Military	31,409	571	1.8%
Infrastructure	146,061	8,820	6.0%
Urban Open	145,028	20,381	14.1%
URBAN ONLY:			
Alameda	168,564	7,791	4.6%
Contra Costa	192,006	25,398	13.2%
Marin	52,784	9,601	18.2%
Napa	34,826	2,098	6.0%
San Francisco	29,187	282	1.0%
San Mateo	103,990	8,579	8.2%
Santa Clara	199,139	7,593	3.8%
Solano	102,317	3,312	3.2%
Sonoma	199,470	24,992	12.5%
	Total Miles	In Areas of Mostly Landslides	% of Miles in Areas of Mostly Landslides
INFRASTRUCTURE:			
Roads	33,995	3,588	10.6%
Transit	173	4	2.3%
Rail	951	12	1.3%
Pipelines	32,022	3,532	11.0%
	Total Number	In Areas of Mostly Landslides	% in Areas of Mostly Landslides
CRITICAL FACILITIES:			
Health Care	812	4	0.5%
Schools	2,063	21	1.0%
Bridges	4,159	147	3.5%
Local Government	3,991	108	2.7%

See <http://quake.abag.ca.gov/mitigation/pickdbh2.html>
and <http://quake.abag.ca.gov/mitigation/pickcrit.html>
for more specific information.

Wildfire and exposure of existing land use –

- ◆ Of the 4.36 million acres of land in the Bay Area, 18.4% is in Wildland Urban Interface (WUI) wildfire threat areas, while 59.2% is in the high, very high, or extreme wildfire threat areas in State Responsibility Areas (SRAs).
- ◆ 48.5% of the urban land is in the WUI wildfire threat areas.
- ◆ 21.3% of the urban land is in the SRA wildfire threat areas, versus 71.6% of the non-urban land. This discrepancy is to be expected because the State focuses on non-urban areas.
- ◆ Types of existing urban land uses with the highest percentages in WUI wildfire threat areas are residential (56.3%), mixed residential-commercial (52.0%), urban open (45.8%), and infrastructure use (42.7%).
- ◆ Of the 524,913 acres of urban land in these WUI wildfire threat areas, 62% is residential use.
- ◆ The percentage of urban land located in WUI wildfire threat areas ranged from a high of 72.8% in Marin County and 63.0% in Contra Costa County to lows of 31.7% in Solano County and 39.6% in Santa Clara County.

These percentages are based on information in ***Table 11: Wildfire Hazards and Existing (2000) Land Use***. See Plates 47 and 48, as well as <http://quake.abag.ca.gov/mitigation/pickdbh2.html> for more specific information for individual counties and cities.

Wildfire and exposure of existing infrastructure –

- ◆ While 42.7% of the region's roads and 36.4% of the transit lines are in WUI wildfire threat areas, only 27.8% of the rail is in these areas.
- ◆ While 26.6% of the region's roads are in areas mapped as having high, very high, or extreme wildfire threat, only 5.8% of the transit lines and 10% of the rail lines are in these areas.
- ◆ Data on pipelines, though provided, is not particularly relevant because underground pipelines are not particularly vulnerable to damage from wildfires.

These percentages are based on information in ***Table 11: Wildfire Hazards and Existing (2000) Land Use***. See Plates 47 and 48, as well as <http://quake.abag.ca.gov/mitigation/pickdbh2.html> for more specific information for individual counties and cities.

Wildfire and exposure of existing critical facilities –

- ◆ Of the 812 critical health care facilities in the Bay Area, 38.4% are in WUI wildfire threat areas, while only 0.6% are in areas mapped as having high, very high, or extreme wildfire threat.
- ◆ Of the 2,063 public schools in the Bay Area, 48.6% are in WUI wildfire threat areas, while 2.2% are in areas mapped as having high, very high, or extreme wildfire threat.
- ◆ Of the 2,063 critical facilities owned by cities, counties, and other special districts in the Bay Area, 44.2% are in WUI wildfire threat areas, while 5.1% are in areas mapped as having high, very high, or extreme wildfire threat.
- ◆ These statistics point to the need to ensure that basic fire mitigation measures are undertaken for these exposed facilities.

These percentages are based on information in ***Table 11: Wildfire Hazards and Existing (2000) Land Use***. See Plates 47 and 48, as well as <http://quake.abag.ca.gov/mitigation/pickcrit.html>, for more specific information for individual counties and cities.

TABLE 11: Wildfire Hazards and Existing (2000) Land Use

	Total Acres	Wildland Urban Interface Wildfire Threat	High, Very High, or Extreme Wildfire Threat Areas	% of Land in Wildland Urban Interface Wildfire Threat Area	% of Land in High, Very High, or Extreme Wildfire Threat Area
Total	4,395,975	810,757	2,603,695	18.4%	59.2%
Urban	1,082,285	524,913	230,657	48.5%	21.3%
Non-Urban	3,313,690	285,844	2,373,039	8.6%	71.6%
URBAN ONLY:					
Residential	578,048	325,665	132,685	56.3%	23.0%
Mixed R+C	2,345	1,220	83	52.0%	3.5%
Commercial/ Services	100,396	38,810	9,207	38.7%	9.2%
Mixed C+I	12,137	3,437	232	28.3%	1.9%
Industrial	66,861	18,874	6,903	28.2%	10.3%
Military	31,409	8,088	11,023	25.8%	35.1%
Infrastructure	146,061	62,431	23,272	42.7%	15.9%
Urban Open	145,028	66,388	47,251	45.8%	32.6%
URBAN ONLY:					
Alameda	168,564	71,790	22,361	42.6%	13.3%
Contra Costa	192,006	120,901	43,805	63.0%	22.8%
Marin	52,784	38,428	16,835	72.8%	31.9%
Napa	34,826	15,107	12,322	43.4%	35.4%
San Francisco	29,187	13,880	668	47.6%	2.3%
San Mateo	103,990	54,618	16,478	52.5%	15.8%
Santa Clara	199,139	78,879	17,933	39.6%	9.0%
Solano	102,317	32,404	19,355	31.7%	18.9%
Sonoma	199,470	98,906	80,900	49.6%	40.6%
	Total Miles	Wildland Urban Interface Wildfire Threat	High, Very High, or Extreme Wildfire Threat Areas	% of Miles in Wildland Urban Interface Wildfire Threat Area	% of Miles in High, Very High, or Extreme Wildfire Threat Area
INFRASTRUCTURE:					
Roads	33,995	13,829	9,032	40.7%	26.6%
Transit	173	63	10	36.4%	5.8%
Rail	951	264	95	27.8%	10.0%
Pipelines	32,022	13,084	8,850	40.9%	27.6%
	Total Number	Wildland Urban Interface Wildfire Threat	High, Very High, or Extreme Wildfire Threat Areas	% in Wildland Urban Interface Wildfire Threat Area	% in High, Very High, or Extreme Wildfire Threat Area
CRITICAL FACILITIES:					
Health Care	812	320	5	39.4%	0.6%
Schools	2,063	1,002	46	48.6%	2.2%
Bridges	4,159	1,607	548	38.6%	13.2%
Local Government	3,991	1,763	203	44.2%	5.1%

See <http://quake.abag.ca.gov/mitigation/pickdbh2.html> and <http://quake.abag.ca.gov/mitigation/pickdbh2.html> for more specific information.

Drought exposure of existing land use –

All of the 4.36 million acres of land in the Bay Area is subject to drought.

Dam failure inundation areas and exposure of existing land use –

- ◆ Of the 4.36 million acres of land in the Bay Area, 10.4% are in areas mapped as dam failure inundation areas.
- ◆ 18.5% of the urban land is in these dam failure inundation areas, versus only 7.8% of the non-urban land.
- ◆ Types of existing urban land uses with the highest percentages in these dam failure inundation areas are mixed commercial-industrial complexes (42.4%) and industrial use (31.9%).
- ◆ Of the 200,142 acres of urban land in these dam failure inundation areas, 50% is residential use.
- ◆ The percentage of urban land located in these dam failure inundation areas ranged from a high of approximately 32% in Alameda and Santa Clara counties to lows of 4.8% in Marin County and 6.1% in San Francisco.

These percentages are based on information in ***Table 12: Dam Failure Inundation Areas and Existing (2000) Land Use***. See Plate 53 and <http://quake.abag.ca.gov/mitigation/pickdbh2.html> for more specific information for individual counties and cities.

Dam failure inundation areas and exposure of existing infrastructure –

- ◆ 32.5% of the miles of rail and 24.3% of transit lines in the region are in areas mapped as dam failure inundation areas.
- ◆ On the other hand, 17.6% of the roads and 17.1% of the pipelines are in these areas.
- ◆ The exposure of transit lines is highest in Santa Clara County, where 66.7% of the miles of the Santa Clara VTA are in these areas.
- ◆ The exposure of rail lines to dam failure inundation are highest in Santa Clara County, where 59.6% of the miles of rail are in these areas, and in Alameda County, where 46.1% of the miles of rail are in these areas.

These percentages are based on information in ***Table 12: Dam Failure Inundation Areas and Existing (2000) Land Use***. See Plate 53 and <http://quake.abag.ca.gov/mitigation/pickdbh2.html> for more specific information for individual counties and cities.

Dam failure inundation areas and exposure of existing critical facilities –

- ◆ Of the 812 critical health care facilities in the Bay Area, 25.5% are in areas mapped as dam failure inundation areas.
- ◆ Of the 2,063 public schools in the Bay Area, 19.9% are in areas mapped as dam failure inundation areas.
- ◆ Of the 3,991 critical facilities owned by cities, counties, and other special districts in the Bay Area, 25.8% are in areas mapped as dam failure inundation areas.

These percentages are based on information in ***Table 12: Dam Failure Inundation Areas and Existing (2000) Land Use***. See Plate 53 and <http://quake.abag.ca.gov/mitigation/pickcrit.html>, for more specific information for individual counties and cities.

These high exposures point to the need to ensure the safety of dams in the region. Existing state and federal laws and requirements should be followed.

TABLE 12: Dam Failure Inundation Areas and Existing (2000) Land Use

	Total Acres	In Dam Inundation Area	% of Land in Dam Inundation Area
Total	4,395,975	457,925	10.4%
Urban	1,082,285	200,142	18.5%
Non-Urban	3,313,690	257,783	7.8%
URBAN ONLY:			
Residential	578,048	101,014	17.5%
Mixed R+C	2,345	613	26.1%
Commercial/ Services	100,396	23,842	23.7%
Mixed C+I	12,137	5,149	42.4%
Industrial	66,861	21,328	31.9%
Military	31,409	1,248	4.0%
Infrastructure	146,061	22,353	15.3%
Urban Open	145,028	24,596	17.0%
URBAN ONLY:			
Alameda	168,564	53,705	31.9%
Contra Costa	192,006	18,232	9.5%
Marin	52,784	2,511	4.8%
Napa	34,826	5,570	16.0%
San Francisco	29,187	1,784	6.1%
San Mateo	103,990	9,486	9.1%
Santa Clara	199,139	63,830	32.1%
Solano	102,317	16,766	16.4%
Sonoma	199,470	28,259	14.2%
	Total Miles	In Dam Inundation Area	% of Miles in Dam Inundation Area
INFRASTRUCTURE:			
Roads	33,995	5,984	17.6%
Transit	173	42	24.3%
Rail	951	309	32.5%
Pipelines	32,022	5,482	17.1%
	Total Number	In Dam Inundation Area	% in Dam Inundation Area
CRITICAL FACILITIES:			
Health Care	812	207	25.5%
Schools	2,063	411	19.9%
Bridges	4,159	1,256	30.2%
Local Government	3,991	1,031	25.8%

See <http://quake.abag.ca.gov/mitigation/pickdbh2.html>
and <http://quake.abag.ca.gov/mitigation/pickcrit.html>
for more specific information.

Summary Overview of Impacts of Natural Hazards on the Bay Area

Earthquake Impacts –

The natural disasters with the largest potential impacts on the Bay Area are earthquakes. Most of the damage is due to ground shaking, with relatively little due to liquefaction and landsliding. For example, in the Loma Prieta earthquake, only 1.6% of the \$6 billion in losses could be attributed to liquefaction³⁵, and an even smaller percentage to landsliding. Surface fault rupture can do significant damage to infrastructure systems, depending on the earthquake. (The fault that caused the Loma Prieta earthquake, for example, did not rupture the surface, so there were no losses associated with fault rupture in that earthquake.)

The extent of the impact of earthquake disasters can best be explained using various earthquake scenario events. For example, in a magnitude 6.9 earthquake on the entire Hayward fault (extending from San Pablo Bay to the border of Alameda and Santa Clara counties), ABAG has estimated over 150,000 uninhabitable housing units and 1,700 road closures. The FEMA-developed HAZUS software only estimates 24,000 displaced households, a factor of 6 lower than the ABAG estimates. Part of this discrepancy is due to uncertainty on the impact on wood-frame apartments with parking in the ground floor (“soft-story” apartments). HAZUS estimates the total losses for that earthquake as only \$23 billion (versus actual losses of over \$40 billion in the Northridge earthquake, a smaller magnitude earthquake with a less vulnerable building stock). The Bay Area Economic Forum produced a 2002 report on the impact of this earthquake on *Hetch-Hetchy Water and the Bay Area Economy*³⁶, estimating that the losses associated with failure of that system alone would be \$17.2 billion. Finally, the HAZUS software predicts from 100-700 fatalities in that earthquake scenario, depending on the time of day. These estimates are difficult to evaluate, particularly because they are so tied to the vulnerability of particular systems. For example, fatalities in the BART tube alone could exceed that value if the tube were to rupture catastrophically. Obviously, the current HAZUS estimates are inadequate. Thus, as specified in the ABAG Annex to this plan, ABAG will be working to develop different ways to either refine those estimates or develop alternative ways to express losses and risk during 2005 and early 2006. See ABAG Annex mitigation strategy GOVT-d-2. Any remaining gaps in knowledge following that effort will be identified as part of that effort. The risk and loss estimates will be city-specific.

Weather-Related Impacts –

Past flooding losses have been significant, but not as large as for earthquakes. For example, the January 1997 floods resulted in \$1.8 billion in total damage in California, while the El Nino storms of early 1998 resulted in \$550 million in losses in the entire state, including both flooding and landslides impacts. FEMA documents \$64 million in total repetitive losses in the Bay Area that have been paid by their insurance program since its inception, most of which (\$48 million) has occurred in Sonoma County. The Holland and Webb Tracts levee breaks in 1980 impacted Contra Costa, Sacramento, and San Joaquin counties and resulted in \$17.4 million in damage. However, since 8.9% of the urban land in the Bay Area is within the 100-year flood plain, future

³⁵ Holzer, T.L., ed., 1998. “Introduction” in *The Loma Prieta, California, Earthquake of October 17, 1989 – Liquefaction*. U.S. Geological Survey Prof. Paper 1551-B: Reston, VA, pp. B4.

³⁶ See <http://www.bayeconfor.org/pdf/hetchhetchyfinal2.pdf> to view the entire report.

losses could be more significant than in the past. Note that some of the repetitive loss claims have occurred in areas outside of the mapped 100-year flood plain, it is also clear that other areas are susceptible to flooding, but to a lesser extent.

Losses from landslides are typically lower than associated flooding. However, in the El Nino storms of early 1998, USGS documented approximately \$150 million in losses due to approximately 300 landslides that occurred in the Bay Area and Santa Cruz County³⁷. The landslides ranged in size from a 25 m³ failure of engineered material to a reactivation of the massive (13 million m³) Mission Peak earthflow complex in Alameda County.

The largest urban-wildland fire in the Bay Area, the 1991 fire in the East Bay Hills, resulted in \$1.7 billion in losses. In that fire, 3,354 family dwellings and 456 apartments were destroyed, while 25 people were killed and 150 people were injured. It is unlikely that any single fire disaster in the Bay Area would exceed that fire in total losses.

The report on *Hetch-Hetchy Water and the Bay Area Economy* discussed earlier hints at the importance of water to the region and the potential impacts of drought and population growth. That report notes on page 5 that:

Based on conditions during the most recent drought period, SFPUC now has determined that the maximum quantity of water it can reliably deliver to its customer base is 239 mgd annually. However, actual demand in 2000-2001 was nearly 260 mgd, and it is generally understood that the SFPUC system is operating in excess of its assured supply capacity and approaching its actual delivery capacity.

Total demand for Hetch Hetchy water is expected to grow to 303 mgd in 2030 and 310 mgd by 2050. Absent a significant expansion of the system, the shortfall relative to assured supply will therefore increase from 21 mgd presently to 64 mgd within 30 years and 71mgd within 50 years.

Most Bay Area water districts develop long-term water supply and management plans, including urban water shortage contingency analyses. ABAG will be working with water districts and others on this issue, as specified in the ABAG Annex, Mitigation Strategy INFR-d-4 and ENVI-a-4 and ENVI-a-5.

Catastrophic failure of a dam in the region would result in huge losses. While damage losses have not been quantified, the areas subject to dam failure inundation include 18.5% of the urban land in the Bay Area.

Lack of understanding of potential impacts of global warming on the region leads to further uncertainties in estimating weather-related losses and impacts.

Again, more work is needed in estimating the impacts of weather-related disasters. Thus, as specified in the ABAG Annex to this plan, ABAG will be working to develop different ways to express losses and risk during 2005 and early 2006. See ABAG Annex mitigation strategy GOVT-d-2. Any remaining gaps in knowledge following that effort will be identified as part of that effort. The risk and loss estimates will be city-specific.

³⁷ Godt, J.W. , ed., 1999. "Introduction" in *Maps Showing Locations of Damaging Landslides Caused by El Nino Rainstorms, Winter Season 1997-98, San Francisco Bay Region, California*: U.S. Geological Survey Misc. Field Studies Map MF 2325-A-J: Reston, VA. See <http://pubs.usgs.gov/mf/1999/mf-2325/>.